JOURNAL OF
FOREST ECONOMICS

UMEÅ FOREST UNIVERSITY PRESS

COMPARATIVE ADVANTAGE IN U.S. INTERSTATE FOREST PRODUCTS TRADE

JEFFREY P. PRESTEMON AND JOSEPH BUONGIORNO*

ABSTRACT

According to the Heckscher-Ohlin-Vanek theorem, the net exports of a region are determined by relative abundance of the immobile factors of production. Empirical tests of this theory, usually at a high level of aggregation, have frequently not supported it. We find, instead, that data on interstate trade in wood products within the United States are in strong agreement with the theorem. Other things equal, net exports of wood products are strongly and positively related to the stock of forest resources. The simplest evidence is the correlation of net exports with forest growing stock, per dollar of state product. A more formal development of the theory leads to a linear model where net exports are negatively related to gross state product and positively related to forest resources. The model predicts better the net exports of lumber and wood products (SIC 24) than those of paper and allied products (SIC 26). For both industries, and for their sum, the marginal effect of additional hardwood growing stock on net exports is larger than that of softwood. However, given the variation in hardwood and softwood growing stock among states, both types of resource were equally important in determining the variation in comparative advantage. The empirical HOV models changed little from 1976 to 1991, except for a decrease in the relative importance of softwood growing stock as a determinant of net exports.

Keywords: Heckscher-Ohlin-Vanek, trade, comparative advantage, lumber, wood products, pulp and paper, competitiveness, econometrics, market, United States, forest resources.

~

INTRODUCTION

Comparative advantage embodies a region's endowment of factor inputs, level of technological development, factor productivity, transfer costs, and other variables (Harkness & Kyle, 1975; Harkness 1983). According to the classical Heckscher-Ohlin-Vanek (HOV) theorem of international trade, the comparative advantage of a region can be traced to its level of endowments of immobile factor inputs, other

* Jeffrey P. Prestemon, Forestry Sciences Laboratory, United States Department of Agriculture-Forest Service, P.O. Box 12259, Research Triangle Park, North Carolina, 27709, U.S.A. jprest@rtpmail.emapfhm.gov

Joseph Buongiorno, Department of Forestry, 1621 Linden Drive, University of Wisconsin, Madison, Wisconsin, 53706, U.S.A. jbuongio@facstaff.wisc.edu

things being equal. For example, if the determinants of competitiveness in the economies of two regions are equal in every respect except endowment of land, the region with the greater land endowment should be more competitive in exporting products that use land intensively in production.

This simple, almost intuitive idea has had mixed success in empirical tests (Bowen et al., 1987; Tamor, 1987; Noussair ef al., 1995; Trefler, 1995). In forestry economics, there have been few tests of the HOV hypothesis. UNIDO (Anonymous, 1983) concluded, from a simple index of comparative advantage, that: "There can be no ambiguity concerning the primary source of comparative advantage in wood products: . ..most of the major exporters have substantial natural forests." Bonnefoi & Buongiorno (1990) did econometric tests of the HOV theorem with international forest products data and found that: "This simple model explained a surprisingly large portion of the variation in net trade... for all commodities forest endowment had a strong positive effect on net trade."

However, the study of Bonnefoi and Buongiorno can be criticized for using roundwood production as a measure of forest endowment. This can be justified by the argument that resource endowment should be measured not by its extent but by the flow of goods and services that derive from it (Learner, 1984). Still, Balassa (1979, 1986) preferred not to investigate resource-based industries at all, due to the difficulty of measuring resource stock.

But accurate data on forest resource stock are available in some instances, and they can be used directly in a test of the HOV hypothesis. Here, data from states within the United States are used to that end. States are first ranked with a simple index of revealed comparative advantage in lumber and wood products and paper and allied products, in 1976 and 1991. Next, Learner's (1984) formulation of the HOV hypothesis is applied to explain comparative advantage, and tested with interstate data for 1976, 1986, and 1991. The results support the HOV hypothesis and document how the forest resource, and its composition in hardwoods and softwoods, have influenced the comparative advantage of the states in forest products. The relationships have changed little over time, thus forest resources continue to determine comparative advantage, despite other changes in the economy.

INDICES OF REVEALED COMPARATIVE ADVANTAGE

A standard index of the comparative advantage of a region in trade is the ratio of its net exports to a measure of the size of the domestic market (e.g. GNP in the case of countries). This revealed comparative advantage (RCA) index has been applied extensively in the past to rank economies (Balassa, 1973 and 1977; Bowen, 1983a and 1986; Bowen, Learner & Sveikauskas, 1987). The intuition is that, if an economy devotes more of its total resources in production of a good than needed to meet domestic demand, it is revealing that it has a comparative advantage over others in the production of the good (Bowen, 1983b).

How well the RCA index measures comparative advantage depends on the characteristics of the good in question, geography, market efficiency, the resources used to make the good, and the policies of interacting economies (Baldwin, 1979; Learner, 1984; Ballance, Forstner & Murray, 1985; Balassa, 1986).

Although the RCA is typically applied to countries, in market economies it should also apply to smaller regions, such as states. In fact, some of the assumptions of the theory, described below, linking the RCA to the resource base are more likely to be valid in free-trading states within the same country than in countries separated by tariff or non-tariff barriers.

Tables 1 and 2 rank states within the United States according to their relative comparative advantage in the production of lumber and wood products (SIC 24) and paper and allied products (SIC 26). The tables show RCA indices for the years 1976 and 1991, in dollars of net exports per hundred dollars of gross state product. Positive values indicate exports greater than imports and a relative comparative advantage, while negative values indicate imports greater than exports and a relative disadvantage.

Notable in these tables is how a few states dominate the RCA rankings and how stable these rankings have been over the period of observation. In lumber and wood products (SIC 24, Table 3), Oregon and Idaho clearly dominate,

TABLE 1. REVEALED COMPARATIVE ADVANTAGE FOR LUMBER **AND WOOD PRODUCTS** (SIC **24**), BY STATE.

Oregon *and Idaho clearly dominated the rest of the country in one measure of comparative advantage, the RCA index (dollars of state net exports of SIC 24 per hundred dollars of gross state product), in both 1976 and 1991. A cohort of about five other states showed lesser but also strongly competitive positions.*

1976		1991	
STATE	RCA	STATE	RCA
Oregon	19.51	Oregon	13.55
Idaho	9.09	Idaho	7.11
Washington	6.81	Montana	4.96
Montana	4.59	Maine	4.69
Mississippi	3.94	Mississippi	4.66
Maine	3.76	Arkansas	3.52
Arkansas	3.67	Washington	3.21
Alabama	1.66	Alabama	2.34
Georgia	1.42	Vermont	1.29
Vermont	1.35	Wisconsin	1.08
South Carolina	1.34	North Carolina	1.01
New Hampshire	1.05	Minnesota	0.97
North Carolina	1.01	South Carolina	0.95
Wisconsin	0.50	Georgia	0.75
Virginia	0.30	Indiana	0.55
Minnesota	0.19	Alaska	0.47
Louisiana	0.11	Virginia	0.28
Indiana	0.10	Louisiana	0.26
South Dakota	-0.07	South Dakota	0.24
California	-0.08	New Hampshire	0.04
Tennessee	-0.24	Kentucky	0.01
Alaska	-0.26	Tennessee	-0.09
Kentucky	-0.37	Wyoming	-0.15
Utah	-0.60	Iowa	-0.17
West Virginia	-0.61	Pennsylvania	-0.20
Arizona	-0.61	California	-0.38
Texas	-0.61	Ohio	-0.39
Iowa	-0.68	New Mexico	-0.39
Pennsylvania	-0.73	Arizona	-0.46
Nebraska	-0.74	Michigan	-0.47
Colorado	-0.76	Utah	-0.50
Florida	-0.81	Florida	-0.51
Missouri	-0.83	Texas	-0.56
New Mexico	-0.84	Oklahoma	-0.56
Kansas	-0.89	Missouri	-0.58
Michigan	-0.90	Nebraska	-0.72
Oklahoma	-0.93	Maryland	-0.83
Ohio	-0.94	Illinois	-0.88
Wyoming	-0.95	Nevada	-0.95
Maryland	-0.98	Massachusetts	-0.97
Illinois	-1.04	Colorado	-0.98
Nevada	-1.09	Connecticut	-0.98
Delaware	-1.10	New York	-0.99
Massachusetts	-1.14	New Jersey	-1.09
New Jersey	-1.19	New York	-1.20
Hawaii	-1.27	North Dakota	-1.31
Rhode Island	-1.34	Connecticut	-1.40
District of Columbia	-1.44		

TABLE 2. REVEALED COMPARATIVE ADVANTAGE FOR PAPER **AND ALLIED PRODUCTS(SIC 26).**

Maine and Wisconsin had the highest comparative advantage in pulp and paper in the United States, as measured by the RCA index (dollars of state net exports of SIC 26 per hundred dollars of gross state product), in both 1976 and 1991. Six other states also expressed strong comparative advantages.

1976		1991	
STATE	**RCA**	**STATE**	**RCA**
Maine	17.96	Maine	13.53
Wisconsin	7.87	Wisconsin	8.55
New Hampshire	5.23	Arkansas	5.73
Alabama	5.17	Alabama	5.04
Arkansas	4.88	South Carolina	3.72
Georgia	3.90	Mississippi	3.48
South Carolina	3.61	Georgia	3.07
Vermont	3.31	Oregon	2.36
Washington	2.90	Tennessee	1.50
Oregon	2.79	Louisiana	1.46
Tennessee	1.61	Washington	1.39
Louisiana	1.55	Vermont	1.36
Minnesota	1.54	Minnesota	0.91
Mississippi	1.46	Pennsylvania	0.69
Massachusetts	0.96	North Carolina	0.56
Pennsylvania	0.74	New Hampshire	0.53
North Carolina	0.69	Kentucky	0.21
New Jersey	0.29	Missouri	0.10
Virginia	0.19	Ohio	0.05
Ohio	-0.14	Delaware	-0.10
Florida	-0.16	Oklahoma	-0.13
Michigan	-0.38	Virginia	-0.15
Missouri	-0.53	Michigan	-0.22
Connecticut	-0.55	Illinois	-0.29
Illinois	-0.62	Iowa	-0.29
Kentucky	-0.65	Massachusetts	-0.32
Indiana	-0.66	Connecticut	-0.34
Maryland	-0.93	Kansas	-0.45
New York	-1.00	New Jersey	-0.78
Rhode Island	-1.07	Rhode Island	-0.83
California	-1.16	Florida	-1.08
Iowa	-1.18	Texas	-1.10
Texas	-1.47	Maryland	-1.20
Oklahoma	-1.54	New York	-1.30
West Virginia	-1.99	California	-1.32
Arizona	-2.12	Utah	-1.45
Colorado	-2.18	Colorado	-1.70
Nebraska	-2.21	Arizona	-1.74
		West Virginia	-1.84

with a second tier of about five states also showing strong comparative advantage. While the rankings of these top seven states differ by year, their general dominance is stable.

Table 1 also shows the declining importance of wood products exports to the economies of the Pacific Northwest. While in 1976 Oregon's lumber and wood product net exports were near 20 percent of total gross state product, by 1991 they had decreased to 14 percent. A similar decline occurred for Idaho and Washington. Although Oregon and Idaho remained first and second, Washington dropped from third to seventh, overtaken by Montana, Maine, Mississippi, and Arkansas.

For SIC 26, Maine and Wisconsin had the highest ranks in revealed comparative advantage in both 1976 and 1991 (Table 2). Noteworthy is the rise in the RCA's of several southern states, which brought Tennessee and Louisiana within the top ten in 1991, displacing Vermont and New Hampshire.

While the RCA indices are useful to rank states according to comparative advantage, establishing the link with resource endowment calls for a theory such as the HOV model.

THE HOV MODEL

The Heckscher-Ohlin-Vanek, or HOV, model (Heckscher, 1919; Ohlin, 1933; Vanek, 1963) has long been the cornerstone of the theory of comparative advantage. It predicts that a region's net exports of a given good are a positive function of its resource endowment and a negative function of its income. The HOV model has been tested mostly with international data, at highly aggregated levels (Harkness, 1978; Maskus, 1985; Bowen, Learner & Sveikauskas, 1987; Tamor, 1987; Brecher & Choudhri, 1988; Staiger, 1988; Kohler, 1991).

Several assumptions underlie the HOV model, including that: (i) there are factors that are immobile between economies; (ii) markets are competitive, with no barriers to trade; (iii) the same technology is available to all producers; (iv) consumption is homothetic with respect to income (Learner, 1984, p. 2). The belief that these premises are not met by international markets, and the disappointing empirical results, have led to alternative models (Helpman & Krugman, 1985; Trefler, 1993, 1995).

Still, the assumptions seem plausible for regions within the United States: products can move freely across state lines, markets are reasonably competitive, technologies are widely available and known throughout the country, and the determinants of demand should be similar in all states. The assumption of resource endowment immobility also holds true for most natural resources, including forests. Here, we propose to test the HOV hypothesis with United States data for forest products, for which the raw material resource base is well defined.

In Learner's (1984, p. 9) formulation of the HOV hypothesis, the vector of immobile factor endowments, **V,** of a state is used to produce the vector of outputs, X, according to the relation:

$$\mathbf{X} = \mathbf{A}^{-1}\,\mathbf{V} \tag{1}$$

where $\mathbf{A}^{-1}$ is the factor-intensity matrix showing how much of each resource is needed per unit of output. Assuming identical homothetic consumption across states, and ignoring foreign trade, the consumption of a state, C, is directly proportional to its income:

$$\mathbf{C} = (Y/Y_{\mathbf{n}})\mathbf{X}_{\mathbf{n}} = s\,\mathbf{X}_{\mathbf{n}} \tag{2}$$

where Y is the state income, Y_n is the total United States income and $\mathbf{X}_{\mathbf{n}}$ is the vector of national production. A state's net exports, T, is therefore:

$$\mathbf{T} = \mathbf{X} - \mathbf{C} = \mathbf{A}\text{-'}(\mathbf{V} - s\mathbf{V}_{\mathbf{n}}) \tag{3}$$

where $\mathbf{V}_{\mathbf{n}}$ is the total United States endowment in immobile factors of production.

Equation (3), the HOV equation, shows that the net exports of a state is related linearly to its excess factor supply, $\mathbf{V} - s\mathbf{V}_{\mathbf{n}}$. For exports of a specific commodity, T, this relationship becomes (Learner, 1984, p. 94):

$$\mathbf{T} = \sum_i \beta_i \left[\mathbf{V}_\mathbf{i} - s\mathbf{V}_{\mathbf{ni}}\right] = \sum_i \beta_i \left[\mathbf{V}_\mathbf{i} - \left(\mathbf{V}_{\mathbf{ni}}/\mathbf{Y}_\mathbf{n}\right)\mathbf{Y}\right] \tag{4}$$

where β_i is the factor intensity of resource *i* in producing the exported commodity, a non-negative element of the matrix **A-'.**

Because the ratio of the United States endowment in factor i to its income, $\mathbf{V}_{ni}/\mathbf{Y}_n$, is fixed at any one point in time, equation (4) leads to the testable relationship:

$$\mathbf{T} = \Sigma_i \beta_i \mathbf{V}_i - g\mathbf{Y}, \tag{5a}$$

or:

$$\mathrm{T/Y} = \Sigma_i \beta_i (\mathbf{V}_i / \mathbf{Y}) - g \tag{5b}$$

where $g = \Sigma_i \beta_i \ (\mathbf{V}_{ni} \ / \mathbf{Y}_n)$ is a constant.

In summary, the HOV hypothesis implies that the net exports of a state should be positively related to its immobile factor endowments, and negatively related to its income. Strict interpretation of the model would also require that the relationship be linear, and that the constant term in an empirical estimate of equation (5a) be not significantly different from zero. Equation (5b) could also be used in a regression of the RCA index on endowments per dollar of gross state product, but such a formulation would force the intercept to be zero. Thus, equation (5a) serves as a more general test of the HOV hypothesis. Still, equation (5b) shows clearly the theoretical link between the RCA indices in Tables 1 and 2, and the forest stock per dollar of gross state product.

EMPIRICAL TESTS OF THE MODEL

The test of the HOV model with interstate trade in forest products employed equation (5a) with data for the years 1976, 1986, and 1991. The empirical version of (5a) was, for lumber and wood products (SIC 24):

$$T_s = \alpha + \beta V_s + \gamma Y_s + \varepsilon_s \tag{6}$$

where, T_s is the net exports of state s, V_s is the net volume (gross volume minus rot and other defects) of sawtimber growing stock in the state, Y_s is its gross state product, ε_s is an error term assumed to be normally distributed, of zero mean and constant variance.

Bonnefoi & Buongiorno (1990) found significant differences in the contributions to comparative advantage made by softwood and hardwood forests. To capture these potential differences, an alternative model was used:

$$T_s = \alpha + \beta_o V_{so} + \beta_h V_{sh} + \gamma Y_s + \varepsilon_s \tag{7}$$

where V_{so} is the softwood sawtimber volume, and V_{sh} the hardwood sawtimber volume in the commercial forests of state s. The theory implies that the β's should be positive, negative and γ equal to zero.

For paper and allied products (SIC 26), the HOV hypothesis was tested with the same equations, (6) and (7), but with V_s replaced by the state growing stock volume, and V_{so} and V_{sh} by the growing stock volumes of softwood and hardwood species, respectively. Indeed, sawtimber-size trees are not needed to make paper products, and sawmill residues that come from sawtimber processing can be used for that purpose.

The data on forest stocks were obtained from Waddell et al. (1989) and Powell ef al. (1994). Although the forest stock data were for slightly different years than the other data (1977, 1987 and 1992, instead of 1976, 1986 and 1991), the yearly variations in sawtimber and growing stock volumes are too small to matter.

Data on gross state product, in current dollars, were obtained from Renshaw et al. (1988) and the United States Department of Commerce (1994). The gross state products of 1976 and 1986 were transformed in constant 1991 dollars by inflation with the United States GDP deflator (International Monetary Fund, various issues).

Few data on trade or consumption are available by state. Therefore, net exports were estimated from state production and gross state product, as follows:

$$T_s = X_s - C_s \tag{8}$$

$$C_s = (X, - T_n)(Y_s / Y_n) \tag{9}$$

where X_s and C_s are state s's production and consumption, respectively, X_n is total national production, T_n is national net exports, and Y_n is the gross national product. Equation (9) assumes that the consumption share of a state is directly proportional to the income share. This homotheticity of demand with respect to income is one of the hypotheses of the HOV model (see equation (2), above), and it is maintained here.

TABLE 3. SUMMARY STATISTICS FOR LUMBER AND WOOD PRODUCTS (SIC 24).

VARIABLE	YEAR	N	MEAN	MINIMUM	MAXIMUM	STANDARD DEVIATION
Net Exports SIC 24	1976	51	-23	-4,102	8,183	1,653
($106, 1991)	1986	46	135	-2,714	8,347	1,644
	1991	44	54	-4,694	7,969	1,883
Gross State Product	1976	51	75,358	6,774	442,374	87,399
($106, 1991)	1986	46	94,170	10,076	671,187	115,482
	1991	44	124,673	11,198	763,577	141,260
Softwood Sawtimber	1977	51	38,879	0	412,086	82,070
(10^6 bf)	1987	46	43,180	7	363,862	82,271
	1992	44	46,409	33	384,055	83,861
Hardwood Sawtimber	1977	51	11,488	0	41,419	11,161
(10^6 bf)	1987	46	16,372	38	52,930	14,669
	1992	44	20,081	38	62,541	17,586
Total Sawtimber	1977	51	50,366	0	430,899	83,601
(10^6 bf)	1987	46	59,552	576	378,638	84,213
	1992	44	66,490	1,990	401,095	85,194

Notes: For Colorado, Florida, South Dakota, and Utah, the 1992 sawtimber volumes were missing and replaced by 1987 data. Summary statistics are for states included in the empirical estimation of HOV equations.

The data on state production of SIC 24 and SIC 26 were the total value of shipments (United States Department of Commerce, 1979, 1988, 1993). Data on total net exports of SIC 24 and 26 from the United States were assembled from OECD (1988, 1992). Net exports of SIC 24 were estimated by adding SITC 24 and SITC 63, and those of SIC 26 by adding SITC 25 and SITC 64. The current values of production and trade in 1976 and 1986 were converted to constant 1991 dollars by inflating with the producer price index for lumber and wood products (for SIC 24), and for paper, pulp, and allied products (for SIC 26) (United States Department of Labor, various issues).

Summary statistics for the data are in Tables 3 and 4. From 1976 to 1991, timber volume changed the least, in mean and standard deviation. Gross state product increased much, both in mean and in standard deviation: the differences between states have increased. There is no obvious trend in net exports. Still, on average, net exports have grown much more slowly than gross state products. Fur-

TABLE 4. SUMMARY STATISTICS FOR PAPER AND ALLIED PRODUCTS(SIC 26).

VARIABLE	YEAR	N	MEAN	MINIMUM	MAXIMUM	STANDARD DEVIATION
Net Exports SIC 26	1976	38	82	-2,334	2,764	870
($106, 1991)	1986	43	-18	-7,156	6,267	2,011
	1991	39	93	-10,049	8,783	2,913
Gross State Product	1976	38	95,137	6,774	442,374	93,380
($106, 1991)	1986	43	116,392	10,076	671,187	127,524
	1991	39	136,166	11,198	763,577	145,591
Softwood Growing	1977	38	8,908	6	74,735	16,042
Stock	1987	43	8,649	4	61,006	14,152
(10^6 ft^3)	1992	39	8,810	9	62,974	14,247
Hardwood Growing	1977	38	6,641	220	21,625	4,903
Stock	1987	43	6,960	276	19,983	5,563
(10’ ft^3)	1992	39	8,284	376	23,690	6,223
Total Growing	1977	38	15,548	413	79,554	16,687
Stock (10^6 ft^3)	1987	43	15,609	280	65,951	15,371
	1992	39	17,094	428	68,222	15,563

Notes: For Colorado and Florida, the 1992 growing stock data were missing and replaced by 1987 data. Summary statistics are for states included in the empirical estimation of HOV equations.

thermore, while the standard deviation of net exports in lumber and wood products has remained about constant, the standard deviation in paper and allied products has more than tripled in 15 years: some states have become much larger net exporters than others.

The maxima, minima, and standard deviations show that there were large differences across states for all three years examined. Although this variability was helpful to get accurate estimates of models (6) and (7), it led to heteroscedastic residuals. This was corrected by applying White’s (1980) method to get efficient estimates.

RESULTS

Lumber and Wood Products (SIC 24)

The results for equations (6) and (7), for lumber and wood products (SIC 24) are in Table 5. The equations were estimated for 44 to 51 states that had complete data for 1976, 1986 and 1991. As shown by the R^2’s, the equations ex-

TABLE 5. LUMBER AND WOOD PRODUCTS (SIC 24) REGRESSION.

Regression of net exports of lumber and wood products (SIC 24) on gross state product and sawtimbergrowing stock under two specifications and three periods, and aggregated across all three periods.

YEAR	R^2	CONSTANT	GSP ($\$10^6$)	SAWTIMBER STOCK (10^6 BF)		
				TOTAL	SOFTWOOD	HARDWOOD
1976	**0.86**	**-71**	**-0.011**	**0.017**		
		(83)	**(0.001)** **	**(0.002)** **		
1986	**0.72**	**107**	**-0.010**	**0.016**		
		(135)	**(0.002)** **	**(0.004)** **		
1991	**0.83**	**203**	**-0.010**	**0.017**		
		(151)	**(0.001)** **	**(0.002)** **		
All	**0.81**	50	**-0.010**	**0.017**		
F = 1.53		**(69)**	**(0.001)** **	**(0.002)** **		
1976	**0.87**	**-221**	**-0.011**		**0.016**	**0.035**
		(107) *	**(0.001)** **		**(0.002)** **	**(0.005)** **
1986	**0.75**	**-148**	**-0.011**		**0.015**	**0.038**
		(112)	**(0.002)** **		**(0.004)** **	**(0.006)** **
1991	**0.86**	**-116**	**-0.011**		**0.017**	**0.038**
		(129)	**(0.001)** **		**(0.003)** **	**(0.004)** **
All	**0.84**	**-191**	**-0.011**		**0.016**	**0.038**
F = 0.51		**(61)** **	**(0.001)** **		**(0.002)** **	**(0.003)** **

Notes: **Net exports and gross state product (GSP), in millions of 1991 dollars. Standard errors in parentheses. * denotes statistical significance at 5%, ** at 1%. F = test of whether coefficients are equal in 1976, 1986, and 1991.**

plained 72 to 86 percent of the variation in net exports in any year. More important, as expected from the HOV theory, net exports were higher for states that had higher resource stocks and lower gross state products. Coefficients of sawtimber stock and gross state product were statistically significant at the 1 percent level. Also as expected from theory, the constant term was not significantly different from zero. From 1976 to 1991, this relationship was remarkably stable, the coefficients staying almost constant at – 0.010 ($ of exports per $ of GSP), and 0.017 ($ of exports per board foot of sawtimber volume).

Disaggregating the forest endowment into softwood and hardwood components provided little additional explanatory power. If one accepts the direction of causality suggested by the theory, the disaggregation suggests that hardwood sawtimber was more important, at the margin, than softwood sawtimber in determining comparative advantage for lumber and wood products.

However, because the variation in softwood sawtimber volume between states is much larger than that of hardwood (Table 3), the differences in comparative advantage for SIC 24 are determined in large part by the softwood sawtimber stock. Again, the relationships between net exports, gross state product, and hardwood and softwood growing stock were very stable from 1976 to 1991. The gross state product coefficient remained constant at -0.011, while the other two coefficients changed very little. The statistical tests, which are almost superfluous here, confirmed this stability.

Paper and Allied Products (SIC 26)

The results of the tests of the HOV model for paper and allied products are in Table 6. Equations (6) and (7) explained less of the variation in net exports than for lumber and wood products. Nevertheless, when total (softwood plus hardwood) growing stock was used to measure resource endowment, the gross state product and endowment variables had the expected signs and were significantly different from zero at least at the 5 percent level. From 1976 to 1991, the marginal effect of the gross state product almost tripled, and that of the growing stock almost quadrupled.

The model with total growing stock had a statistically significant constant term, which is contrary to the theory, and suggests a specification error. This problem was reduced by dividing the growing stock into softwood and hardwood. The results in the lower part of Table 6 show that the fit was improved, and the constant term was not statistically significant, except in 1991. The marginal effect of the gross state product was almost the same in the two formulations.

Notable is the large difference in the marginal effects of the growing stocks of softwood and hardwoods. On aver-

TABLE 6. PAPER AND ALLIED PRODUCTS (SIC 26) REGRESSION.

Regression of net exports of paper and allied products (SIC 26) on gross state product and growing stock volumes, under two specifications and three periods, and aggregated across all three periods.

YEAR	R^2	CONSTANT	GSP ($\$10^6$)	GROWING STOCK (10^6 FT^3)		
				TOTAL	SOFTWOOD	HARDWOOD
1976	0.39	464 (168) **	-0.006 (0.001) **	0.012 (0.006) *		
1986	0.47	844 (307) **	-0.012 (0.002) **	0.031 (0.012) **		
1991	0.51	1460 (465) **	-0.016 (0.002) **	0.044 (0.019) *		
All F = 3.86’	0.46	989 (222) **	-0.012 (0.002) **	0.028 (0.008) **		
1976	0.50	141 (114)	-0.006 (0.001) **		0.007 (0.004)	0.072 (0.020) **
1986	0.59	245 (189)	-0.013 (0.001) **		0.014 (0.008)	0.156 (0.045) **
1991	0.59	655 (303) *	-0.016 (0.002) **		0.021 (0.012)	0.171 (0.052) **
All F = 3.44*	0.56	365 (148) *	-0.013 (0.001) **		0.013 (0.006) *	0.143 (0.027) **

Notes: Net exports and gross state product (GSP), in millions of 1991 dollars. Standard errors in parentheses. * denotes statistical significance at 5%, ** at 1%. F = test of whether coefficients are equal in 1976, 1986, and 1991.

age, during the years considered, a given difference in hardwoods led to a difference in net exports ten times larger than that due to the same difference in softwoods. This ten-to-one ratio persisted from 1976 to 1991. In addition, the marginal effect of each type of growing stock increased over the period, doubling for hardwood growing stock and tripling for softwood. The statistical tests confirmed the change in the magnitude of the coefficients from 1976 to 1991.

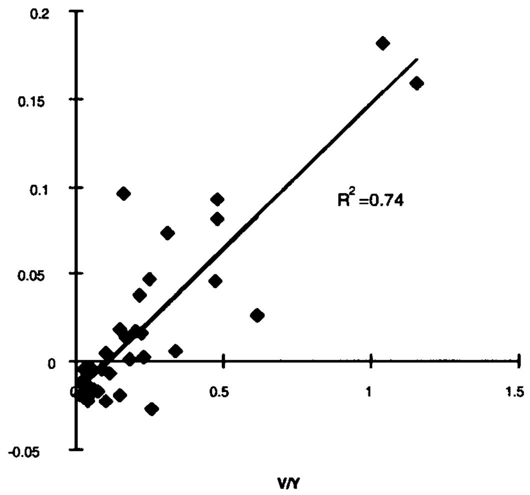

FIGURE **1. NET EXPORTS OF FOREST PRODUCTS VERSUS ENDOWMENT**

This plot of 1991 state net exports of total forest products (SIC 24 & 26) per dollar of gross state product, versus the ratio of commerical timber growing stock volume per dollar of gross state product, reveals a positive correlation between net exports and endowments.

Total Forest Products (SIC 24 and 26)

For some purposes, the distinction between SIC 24 and SIC 26 may not be needed. In fact, the division between the two industries is blurred: production of solid wood and pulp and paper products is often integrated, and to some extent, trees can be used for both purposes. Thus, the HOV theorem was also tested with net exports in total forest products (SIC 24 and 26) as the dependent variable, and total growing stock to measure endowment. Figure 1 shows the simplest test: a regression of the RCA on the growing stock per dollar of gross state product. The coefficient of determination was 0.74, and the null hypothesis rejected at the 1% significance level.

The more general tests, based on equations 6 and 7, also support the HOV hypothesis (Table 7). The variables had all the expected signs, with small standard errors. Again, the data fit the theory better after disaggregating the resource endowment into softwood and hardwood. Also in accord with theory, the constant term was not significantly different from zero. Furthermore, the parameters were very

TABLE 7. TOTAL FOREST PRODUCTS REGRESSION.

Regression of nef exports of total forest products (SIC 24+26) on gross state product and growing stock volumes, under two specifications and three periods, and aggregated across all three veriods.

YEAR	R^2	CONSTANT	GSP ($\$10^6$)	GROWING STOCK (10^6 FT^3)		
				TOTAL	SOFTWOOD	HARDWOOD
1976	0.79	609	-0.025	0.125		
		(345)	(0.002) **	(0.006) **		
1986	0.67	674	-0.024	0.134		
		(443)	(0.003) **	(0.018) **		
1991	0.75	1546	-0.028	0.146		
		(573) *	(0.002) **	(0.014) **		
All	0.73	863	-0.025	0.135		
F=1.83		(255) **	(0.002) **	(0.008) **		
1976	0.79	234	-0.026		0.119	0.194
		(288)	(0.002) **		(0.007) **	(0.047) **
1986	0.72	-96	-0.025		0.114	0.282
		(282)	(0.003) **		(0.024) **	(0.063) **
1991	0.78	632	-0.028		0.128	0.278
		(507)	(0.002) **		(0.015) **	(0.058) **
All	0.77	130	-0.026		0.120	0.264
F=1.32		(199)	(0.001)		(0.009)	(0.033)

Notes: Net exports and gross state product (GSP), in millions of 1991 dollars. Standard errors in parentheses. * denotes statistical significance at 5%, ** at 1%. F = test of whether coefficients are equal in 1976, 1986, and 1991.

stable from 1976 to 1991, with no significant difference detected by the F-test, at the 5 percent level.

Disaggregating the endowment by species showed that differences in hardwood growing stock were twice as important as differences in softwood, at the margin. However, this does not mean that more of the variation in net exports across states is explained by the hardwood than by the softwood growing stock, because the variation in softwood growing stock is larger than that of hardwood (see standard deviations in Tables 3 and 4).

The beta coefficients in Table 8 show how each variable affects the variation of net exports across states. Each is the difference in net exports (in standard deviations) due

TABLE 8. BETA COEFFICIENTS OF EFFECTS.

Effects of gross state product and growing stock on net exports of forest products (SIC 24+26), in standard deviations. The effects are calculated as beta coefficients, $\beta_x = b_x (S_x/S_y)$, b_x = regression parameter of variable x in Table 7. S_x and S_y are standard deviations of x and net exports, respectively, across states.

YEAR		GROWING STOCK	
	GSP	SOFTWOOD	HARDWOOD
1976	-0.76	0.59	0.30
1986	-0.84	0.47	0.44
1991	-0.72	0.41	0.35
All years	-0.82	0.48	0.38

to one standard deviation difference in gross state product, softwood growing stock, or hardwood growing stock. These beta coefficients show that the variation in softwood growing stock explained more of the variation in net exports than the variation in hardwood stock.

The data in Table 8 suggest that the importance of softwood growing stock declined during the interval. Although the differences are not statistically significant, the trend is consistent with other evidence of the increasing importance of hardwood forest resources in the manufacture of both solid wood and paper products (Skog et al., 1995). The beta coefficients in Table 8 also show that softwood and hardwood resources must both be one standard deviation higher to compensate for one standard deviation difference in gross state product and keep two states at the same level of net exports.

SUMMARY AND DISCUSSION

According to the Heckscher-Ohlin-Vanek factor endowment model of comparative advantage, regions with more abundant forest resources should have larger net exports of forest products, other things being equal. This prediction was largely confirmed with interstate data from the United States. After controlling for the size of the state market, there was a strong positive relationship between the states' net exports and their forest endowments. This relationship was stable over time, implying that the location of the forest resource remains important in explaining the geographical distribution of forest industries within the United States.

Disaggregation of the forest endowment into coniferous and hardwood components suggested that a marginal difference in the hardwood stock had a larger effect on net exports than a marginal difference in the softwood stock. This was true for lumber and wood products as well as for paper and allied products. But, in terms of explaining the total variation in net exports across states, the differences between softwood and hardwood resources was equally important. There may have been a slight decrease in the relative importance of softwood over time.

This confirmation of the Heckscher-Ohlin theorem for forest products contrasts with previous results for broader sectors (Maskus, 1985; Bowen, Learner & Sveikauskas, 1987; Brecher & Choudhri, 1988; Staiger, 1988; Kohler, 1991). Trefler (1993) ascribed the failures to the HOV assumption of factor price equalization and identical technologies, which do not hold across countries. These assumptions are more likely to be true with interstate data. The results also validate Vanek's (1963) specialized resource theory: a state's comparative advantage in forest products can largely be explained by the size of its economy and its endowment of the forest resources. This seems also to be the case for countries (Bonnefoi & Buongiorno, 1990).

A limitation of the analysis is that the state net export data were estimated by assuming that the ratio of a state's consumption to gross state product was proportional to its share of gross domestic product. This homotheticity hypothesis is part of the HOV hypothesis itself, and the fact that the results are coherent with HOV suggests that one could proceed as if consumption were indeed homothetic. However, it may be possible to test directly this maintained hypothesis.

This study dealt with intermediate wood products only. A more complete analysis of comparative advantage could cover also exports of final products, such as furniture and printed materials. Thus, an extension of this study could be to compute the full resource content of trade, possibly with an input-output table, and then test its correlation with forest resources.

Endowments other than forest resources could affect net exports; labor and capital come to mind first. However, the HOV theory refers specifically to immobile endowments

(Learner, 1984, p. 22), while labor and capital within the United States are quite mobile. Indeed, when measures of labor and capital endowments were added, they had weak or insignificant relationships with net exports. Further, the coefficients of forest endowments never changed sign, changed little in magnitude, and maintained their statistical significances. Still, the volume of growing stock is an imperfect measure of forest resource endowment. Disaggregation according to soft and hardwoods improved the results, but so would recognition that forests grow differently in different states.

The potential manufacturing cost and productivity advantages enjoyed by regional concentrations of firms (Bressler & King, 1978, p. 53-52) may also help better explain why some states dominate net exports of forest products. But this would mean changing the strict HOV theory that assumes constant returns to scale and perfectly competitive markets. Furthermore, recycled paper and paperboard are becoming increasingly important sources of fiber, relaxing the industry ties to the forest resource, and thus weakening the relevance of the HOV theorem for paper and allied products. Indeed, the evolution of the degree of forest industry's links with its forest base could be a worthy topic for future investigation.

In spite of these limitations, our findings indicate that the HOV theorem gives a good account of the comparative advantage of forest product industries within the United States. From a measure of the size of the domestic market (gross state product) and a measure of the resource endowment (timber stocks), one can reasonably well predict net exports. That this is contrary to failures of the model with more aggregated data suggests that the fault may lie with the aggregation and with the difficulty of defining the relevant resource, rather than with the HOV theorem itself.

ACKNOWLEDGEMENTS

The research leading to this paper was supported in parts by McIntire-Stennis grant M855, NRI grant 95-37400-1851, the USDA Forest Service Pacific Northwest Forest and Range Experiment Station in Portland, the USDA Forest Service Forestry Sciences Laboratory at Research Triangle Park, North Carolina, and by the School of Natural Resources of the University of Wisconsin at Madison. We thank David Brooks for his cooperation. We also thank Jan Laarman and John Perez-Garcia for helpful and insightful comments.

REFERENCES

Anonymous, 1983. Industry *in a Changing World* (Vienna: United Nations Industrial Development Organization).

Balassa, B., 1973. The Changing Pattern of Comparative Advantage in Manufactured Goods. The *Review of Economics and Statistics, 61, 259-266.*

Balassa, B., 1977. "Revealed" Comparative Advantage Revisited: an Analysis of Relative Export Shares of Ten Industrial Countries, 1953-1971. *The Manchester School of Economics and Social Studies, 45, 327-344.*

Balassa, B., 1979. The Changing Pattern of Comparative Advantage in Manufactured Goods. *The Review of Economics and Statistics,* 61, 315-319.

Balassa, B., 1986. Comparative Advantage in Manufactured Goods: a Reappraisal. *The Review of Economics and Statistics, 68, 259-266.*

Baldwin, R. E., 1979. Determinants of Trade and Foreign Investment: Further Evidence. *The Review of Economics and Statistics, 61, 40-48.*

Ballance, R., H. Forstner & Murray, T., 1985. On Measuring Comparative Advantage: a Note on Bowen's Indices. *Weltwirtschaftliches Archiv, 121, 346-350.*

Bonnefoi, B. &Buongiorno, J., 1990. Comparative Advantage of Countries in Forest-products Trade. *Forest Ecology and Management, 36, 1-17.*

Bowen, H. P., 1983a. Changes in the International Distribution of Resources and Their Impact on U.S. Comparative Advantage. *The Review of Economics and Statistics, 65, 402-414.*

Bowen, H. P., 1983b. On the Theoretical Interpretation of Indices of Trade Intensity and Revealed Comparative Advantage. *Weltwirtschaftliches Archiv, 119, 464-472.*

Bowen, H. P., 1986. On Measuring Comparative Advantage: Further Comments. *Weltwirtschaftliches Archiv, 122, 379-381.*

Bowen, H. P., Learner, E. E. & Sveikauskas, L., 1987. Multicountry, Multifactor Tests of the Factor Abundance Theory. *American Economic Review, 77, 791-809.*

Brecher, R. A., & Choudhri, E. U., 1988. The Factor Content of Consumption in Canada and the United States: a Two-country Test of the Heckscher-Ohlin-Vanek Model. In *Empirical Methods for International Trade*, edited by Robert C. Feenstra (Cambridge, Massachussets: MIT Press), pp. 5-17.

Bressler, R. G. & King, R. A., 1978. *Markets, Prices, and Inferregional Trade* (Raleigh, North Carolina: Norman-Weathers Printing Co. and John Wiley & Sons, Inc.).

Harkness, J., 1978. Factor Abundance and Comparative Advantage. *American Economic Review, 68, 784-800.*

Harkness, J., 1983. The Factor-proportions Model with Many Nations, Goods, and Factors: Theory and Evidence. *The Review of Economics and Statistics, 65, 298-305.*

Harkness, J. & Kyle., J. F., 1975. Factors Influencing United States' Comparative Advantage. *Journal of International Economics, 5, 153-165.*

Heckscher, E. F., 1919. The Effects of Foreign Trade on the Distribution of Income. *Ekonomisk Tidskriff, 21, l-32.*

Helpman, E. & Krugman, P. R., 1985. *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy* (Cambridge, Massachusetts: MIT Press).

International Monetary Fund, various issues. *International Financial Statistics Yearbook* (Washington, D.C.: International Monetary Fund).

Kohler, W., 1991. How Robust are Sign and Rank Order Tests of the Heckscher-Ohlin-Vanek Theorem? *Oxford Economic Papers, 43, 158-171.*

Learner, E. E., 1984. *Sources of International Comparative Advanfuge* (Boston, Massachusetts: MIT Press).

Maskus, K. E., 1985. A Test of the Heckscher-Ohlin-Vanek Theorem: the Leontief Commonplace. *Journal of International Economics, 19, 201-212.*

Noussair, C. N., Plott, C.R. & Riezman, R. G., 1995. An Experimental Investigation of the Patterns of International Trade. *American Economic Review, 85, 462-491.*

OECD, 1988. *Foreign Trade by Commodities, 1987,* Volume 3 (Paris: Organization for Economic Cooperation and Development).

OECD, 1992. *Foreign Trade by Commodities, 1991, Volume 3* (Paris: Organization for Economic Cooperation and Development).

Ohlin, B. G., 1933. *Interregional and International Trade* (Cambridge, Massachusetts: Harvard University Press).

Powell, D. S., Faulkner, J. L., Darr, D. R., Zhu, Z. & MacCleery, D. W., 1994. *Forest Resources of the United States, 1992.* USDA-Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, General Technical Report RM–234.

Renshaw, V., Trott, Jr., E. A. & Friedenberg, H. L., 1988. Gross State Product by Industry, 1963-86. Survey of Current *Business,* 68, 30-45.

Skog, K. E., Ince, P. J., Dietzman, D. J. S. & Ingram, C. D., 1995. Wood Products Technology Trends: Changing the Face of Forestry. *Journal* of *Forestry,* 93, 30-33.

Staiger, R. W., 1988. A SpecificationTest of the Heckscher-Ohlin Theory. Journal of International Economics, 25, 129-141.

Tamor, K. L., 1987. An Empirical Examination of the Factor Endowments Hypothesis. *Canadian Journal of Economics, 2, 387-398.*

Trefler, D., 1993. International Factor Price Differences: Leontief Was Right! *Journal of Political Economy,* 101, 961-987.

Trefler, D., 1995. The Case of Missing Trade and Other Mysteries. *American Economic Review, 85, 1029-1046.*

United States Department of Commerce, 1979. *Annual Survey of Manufactures, 1975-1976, Part 6* (Washington, D.C.: United States Department of Commerce).

United States Department of Commerce, 1988. *Annual Survey of Manufactures, Geographic Statistics* (Washington, D.C.: United States Department of Commerce).

United States Department of Commerce, 1993. *Annual Survey of Manufactures* (Washington, D.C.: United States Department of Commerce).

United States Department of Commerce, 1994. Survey of *Current Business (August)* (Washington, D.C.: United States Department of Commerce).

United States Department of Labor, various issues. *Producer Price Indexes* (Washington, D.C.: United States Department of Labor).

Vanek, J., 1963. The *Natural Resources Content of United States* Foreign *Trade, 1870–1955* (Cambridge, Massachusetts: MIT Press).

Waddell, K. L., Oswald, D. D. & Powell, D. S., 1989. *Forest Statistics of the United States, 2987.* USDA-Forest Service, Pacific Northwest Research Station, Portland, Oregon, Resource Bulletin PNW-RB-168.

White, H., 1980. A Heteroscedasticity-consistent Covariance Matrix and a Direct Test for Heteroscedasticity. *Econometrica 48, 817-838.*